# CONSOLIDATED INFORMATION TECHNOLOGY SERVICES TASK ASSIGNMENT (TA)

1. **TITLE:** (D205) BALLISTIC RANGE DATA REDUCTION

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|---|---|---|---|
| **TA No:** | RAA002-Rev8 | | |
| **Task Area Monitor:** | | **Alternate Task Area Monitor:** | |
| **NASA POC:** | | **Software Control Class:** | Low Control |
| **Type of Task:** | Non-Recurring Task | | |

## 2. BACKGROUND

The CEV project has conducted several ballistic range tests and free/forced oscillation wind tunnel tests on the CEV command module (CM) to obtain dynamic stability aerodynamic coefficients from supersonic to low subsonic speeds across a wide range of angle-of-attack. This effort will attempt to look at all available data (drawing on test data from other blunt capsule tests where appropriate) to compare the relative merits and hinderences of each test technique, quantify the differences in the data extracted from each test (identifying sources of disagreement where possible), and providing recommendations where each facility is best applied in obtaining data for the CEV database.

## 3. OBJECTIVE

The primary objective of this analysis is the comparison of various sets of test data where overlaps in Mach number and Angle-of-Attack exist, quantifying observed differences and identifying sources of error. This type of comparison can be more difficult than the comparison of static force/moment data as two sets of pitch damping data with very different variations with Mach and angle-of-attack can produce very similar behavior when used in a simulation of an oscillating, decelerating blunt body. Therefore the available data shall be used in the simulation of available ballistic range data (here used as validation, scaled, flight data) to demonstrate the integrated effect of the dynamic stability data across Mach number and angle-of-attack.

## 4. GENERAL IT SUPPORT SERVICES

**General IT Support Services Performance Metrics**

Performance Standard: Assigned activities are accomplished satisfactorily and within the pre-determined schedule to permit 1) uninterrupted support of data reduction for the ballistic range tests, and 2) application and successful operational checkout of newly developed/modified software upgrades or enhancements for the reduction of free flight attitude information into aerodynamic coefficients of blunt entry vehicles. See Metrics listed below.

Performance Metrics:

Exceeds: All assigned activities are accomplished satisfactorily on or ahead of the pre-determined schedule. Suggestions are made and acted on that lead to advancements towards the goals of the tests.

Meets: Any deficiencies or slippage in one or more activities are offset by improvements or gains in other activities.

Fails: Deficiencies or slippage in assigned activities have had a detrimental effect on the objectives of the goals of the tests.

## 5. SYSTEM AND APPLICATION DEVELOPMENT SERVICES

Project Title: Ballistic Data Reduction

LaRC Software Manager: Mark Schoenenberger

Software Software Control Class: Low

Responsibilities of Contractor and LaRC personnel:The contractor shall maintain the software tools that were developed for the reduction of free flight attitude information into aerodynamic coefficients of blunt entry vehicles.

**Requirements:**
None

## 6. WORK-AREA SPECIFIC SERVICES

Work Area Title: Ballistic Data Reduction for CEV

LaRC Manager: Mark Schoenenberger

Work Area Description: The contractor shall provide support in comparing aerodynamic test data from various test methods and investigating new data reduction methodologies for the CEV entry capsule.

Work Area Requirements: The contractor shall provide the following:

Task 1: Dataset matrix

The contractor shall generate a matrix of all provided data, highlighting overlaps in common variables and areas where test parameters (OML, Reynolds number, radial cg offset, etc.) differed. From this matrix, the contractor shall identify the data sets that will be compared in the following tasks.

Contractor and NASA will coordinate meeting with representatives from various facilities, where relevant information will be provided to contractor.

Task 2: Ballistic Range/Forced-Oscillation Wind Tunnel Data Comparison
The contractor shall compare and quantify the differences in dynamic stability as measured in dynamic wind tunnel tests and in ballistic range testing. Functional forms shall be fit through each set of wind tunnel test data for which there is comparable ballistic range data.

Simulations using the best fit through wind tunnel dynamic stability data will be run to assess how well wind tunnel data replicates observed free flight data. The coefficients of the functional form shall also be relaxed to identify a best-fit using traditional ballistic range data reduction methods. A comparison of these analyses shall be performed identifying possible sources of discrepancy and an overall comparison of the data.

From this analysis, a final, best aerodynamic model shall be delivered for the range of Mach number and Angle-of-attack appropriate to the available data.

Task 3: Free-to-oscillate/Ballistic Range/Spin Tunnel data reduction comparison.

The contractor shall attempt to identify differences in the measured dynamic stability characteristics due to test setup and data reduction techniques between wind tunnel free-to-oscillate testing and ballistic range results and observed spin-tunnel flight dynamics. The data reduction techniques (including fits through ballistic range data) developed by the contractor for ballistic range testing shall be applied to free-to-oscillate test data. This objective of this task is to isolate the differences caused by sting interference, bearing friction, and other wind tunnel related effects from data reduction techniques and draw conclusions on the relative merit of each test technique. The contractor will document additional data required for a full analysis if needed (e.g. bearing friction measurements).

Qualitative and/or quantitative comparisons between free-to-oscillate and spin tunnel tests data will be conducted if sufficient data exists. NASA LaRC will supply available spin tunnel data to assess the feasibility of these comparisons.

Task 4: Investigation of Alternate Sources of Apparent Damping

The contractor shall investigate any history effects (hysteresis of the nominal pitching moment curve, or frequency/amplitude effects) and how such effects may distort or alter the identification of pitch/yaw damping coefficients in ballistic range as well as forced oscillation and free-to-oscillate wind tunnel tests. This analysis should compare current dynamic stability test techniques and their relative abilities in separating true dynamic stability from these other effects that alter oscillation amplitude growth (or measured damping forces) during testing.

The contractor will suggest any additional testing or improvements to test technique (control of oscillation frequency, amplitude, cg, freestream conditions etc.) that can help identify hysteresis effects.
NASA LaRC shall provide all available static aerodynamic data (wind tunnel and computational) to the contractor. This contractor will attempt to correlate any possible hysteresis effects identified in this analysis with existing static data.

Task 5: Uncertainty Analysis and Applicability Assessment for Alternate Cg Locations

The contractor shall assess the available data sets and document the uncertainties on aerodynamic coefficients identified by forced oscillation and ballistic range techniques (the two test techniques for which there is the most data). This uncertainty analysis should be done for a large sample of data for both techniques. The assessment should identify the significant sources of error associated with the test techniques as well as the amount of data. Particular attention shall be paid to modeling uncertainties such that dynamic stability

curves with dramatically different functional forms (but similar integrated impact on trajectories) are reconciled and not over-conservatively bounded. Strengths and weaknesses of other techniques (e.g. free-to-oscillate and spin tunnel testing) should be addressed as well.

The contractor shall use available data to assess the sensitivity of dynamic stability coefficients to the location of the center-of-gravity. The dynamic forces and moments measured in TDT forced oscillation testing and their derivatives wrt rates shall be used to determine how effectively pitch/yaw damping coefficients may be transferred from on oscillation center to another using the dynamic moment transfer equations. The contractor shall document the moment transfer equations and a process for accounting for added uncertainties due to shifting the MRP, consistent with existing data. If the data does not permit transfer to another rotation center by any meaningful distance, this finding with supporting evidence shall be documented instead.

Task 6: Telemetetry Data Evalutation

The contractor shall assess the available Aberdeen Proving Grounds telemetered ballistic range data collected for CEV. Data will be collected in the first half of calendar year 2008 for this analysis. The data will include magnetometer, rotational rate, accelerometer, and potentially forebody pressure data, all anchored by radar tracking (position and velocity) data. The objective of this task is to assess the data quality and make recommendations regarding how best to use this data. The contractor shall provide analysis showing whether the data can be used to directly solve for dynamic stability coefficients as a function of angle-of-attack and Mach number, or if multiple shots are required just as is done with testing in Eglin AFB and NASA Ames ballistic ranges. NASA LaRC will supply all raw data to the contractor and be responsible for converting forebody pressure data into instantaneous angle-of-attack and sideslip for correlation other rate/accelerometer measurements. The contractor will also assess the suitability of these particular data sets and this type of data in general as validation cases to evaluate aerodynamic databases for use in 6-DoF trajectory simulations.

Task 7: Reporting:

The contractor will supply a preliminary written report 4 months after the start of these tasks. A final written report shall be supplied within 7 months of the start these tasks. Periodic updates of significant and/or unanticipated results, determined prior to these dates, will be communicated to the customer informally by telephone, e-mail etc. Upon completion of the preliminary report, the contractor will then participate in a teleconference with the customer to address and concerns. Three months after this teleconference, the contractor will supply a final report. This report is to include data produced in the completion of Tasks 1-5.

Work Area Title: Ballistic Data Reduction for PAI-DAE

LaRC Manager: Monica Hughes

Work Area Description: The contractor shall provide support in reducing aerodynamic test data to aerodynamic coefficients from ballistic range shots of the Program to Advance Inflatable Decelerators for Atmospheric Entry
(PAI-DAE) sub-scale models.

Work Area Requirements: The following tasks are to be completed [redacted]

Task 1: Static Force and Moment Data Reduction
The contractor will provide axisymmetric static force and moment coefficients: CA, CN, and Cm. The reduced data will capture the nonlinear variation of these coefficients with angle-of-attack and with Mach number. Any anomalous asymmetric data will be noted and quantified. The static data is to be quantified with uncertainties suitable for incorporation into a 6-dof aerodynamic database.

Task 2: Dynamic Force and Moment Data Reduction

The contractor will provide dynamic force and moment coefficients with particular attention given to the pitch-damping coefficient, . The variation of the pitch damping to Mach number and angle-of-attack will be determined. Any anomalous dynamic asymmetric terms will be identified as well. This data is to be quantified with uncertainties suitable for incorporation into a 6-degree-of-freedom aerodynamic database.

Task 3: Trajectory Simulation

The contractor will supply a 6-dof simulation recreating the ballistic range shots using the coefficients derived from the data reduction listed in tasks 1 and 2. This simulation will be displayed with the test data points for comparison to help illustrate the fidelity with which the derived coefficients capture the observed aerodynamics.

Task 4: Comparison of Data Between Configurations

The contractor will quantitatively measure and compare the differences in damping characteristics among the various IAD test configurations. Any significant differences in static aerodynamics will be noted.

Task 5: Reporting:

The contractor will supply a preliminary written report within 8 weeks of receipt of the complete set of raw test data (digitized photos, mass properties and test conditions). Periodic updates of significant and/or unanticipated results, determined prior to this date, will be communicated to the customer informally by telephone, e-mail etc. Upon completion of the preliminary report, the contractor will then participate in a teleconference with the customer and representatives from the Eglin AFB Aero-Ballistic Research Facility to address any concerns of the customer. Two months after this teleconference, the contractor will supply a final report. This report is to include the data calculated in tasks 1 through 4. The report will also describe the sources of the listed data uncertainties and the methods with which they were calculated.

## 7. Exhibit A

None required.

## 8. SPECIAL SECURITY REQUIREMENTS

Except where specifically required and approved by the Government, data release by the contractor to third parties is strictly prohibited.

## 9. SOFTWARE ENGINEERING PROCESS REQUIREMENTS

None required.

## 10. JOINT REVIEW SCHEDULE

For the CEV analysis, the contractor will supply a preliminary written report for each task on the delivery dates specified. Following the receipt of those reports, the contractor will participate in telecons to disuss the findings. This should occur within two weeks of the deliverable delivery dates.

A summary meeting will be held at the end of the period of performance to present an overview of the analysis completed for this task to the CEV project. The contractor will present their summary in person at a meeting place convenient to the CEV project and the contractor.

## 11. PERIOD OF PERFORMANCE

This TA is effective from 01/01/05 to 04/27/09

## 12. TECHNICAL PERFORMANCE RATING

In evaluating Technical Performance, quality and timeliness shall be rated as follows:

Quality: 60% Timeliness: 40%

## 13. RESPONSE REQUIREMENTS

Within two weeks from the receipt of this task assignment, submit to the Contracting Officer's Representative, an original and two copies of a Task Plan. This Task Plan shall address the contractor's lead personnel; specific work plans; and the associated estimated labor hours, cost and schedule. Include a signature block for concurrence by the Contract Manager and approval by the Contracting Officer's Representative.

## 14. FUNDING INFORMATION

Funding has not been entered for this TA.

## 15. MILESTONES

| Date | MileStones |
|---|---|
| 04/01/2008 | Dataset matrix of all data to be evaluated, noting overlaps from data set to data set. |
| 06/01/2008 | Comparison of forces oscillation results with ballistic range trajectory data. |
| 08/01/2008 | Free-to-oscillate, spin tunnel, ballistic range test technique comparison |

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|---|---|
| 09/30/2008 | Hysteresis evaluation |
| 12/31/2008 | Uncertainty analysis |
| 12/31/2008 | Assessment of Aberdeen Proving Ground telemetry data for use in dynamic coefficient identification and as validation data set. |

## 16. DELIVERABLES

| Number | Deliverable Item | Deliverable Schedule |
|---|---|---|
| 1 | Data matrix report | 04/1/2008 |
| 2 | Forced Oscillation/Ballistic Range comparison report | 06/01/2008 |
| 3 | Free-to-oscillate,Spin Tunnel Ballistic Range comparison report | 08/01/2007 |
| 4 | Hysteresis evaluation report | 09/30/2008 |
| 5 | Uncertainty analysis report | 12/31/2008 |
| 6 | 12/31/2008 | Aberdeen Proving Ground telemetry assessment report |

## 17. FILE ATTACHMENTS

Others1